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For

**METHOD AND APPARATUS FOR SELECTIVE INJECTION OR FLOW
CONTROL WITH THROUGH-TUBING OPERATION CAPACITY**

By

Ronald E. Pringle and Arthur J. Morris

EL 765784607US

METHOD AND APPARATUS FOR SELECTIVE INJECTION OR FLOW CONTROL WITH THROUGH-TUBING OPERATION CAPACITY

5 **Related Applications.** The present application is a continuation-in-part of
U.S. patent application no. 09/441,701 filed November 16, 1999 which claims
priority to U.S. Provisional application no. 60/108,810 filed November 17, 1998.

Field of Invention. The present invention relates to subsurface well
equipment and, more particularly, to a method and apparatus for remotely controlling
10 injection or production fluids in well completions which may include gravel pack.

Description of the Related Art. As is well known to those skilled in the art,
certain hydrocarbon producing formations include sand. Unless filtered out, such
sand can become entrained or commingled with the hydrocarbons that are produced
to the earth's surface. This is sometimes referred to as "producing sand", and can be
15 undesirable for a number of reasons, including added production costs, and erosion
of well tools within the completion, which could lead to the mechanical
malfunctioning of such tools. Various approaches to combating this problem have
been developed. For example, the industry has developed sand screens which are
connected to the production tubing adjacent the producing formation to prevent sand
20 from entering the production tubing. In those cases where sand screens alone will
not sufficiently filter out the sand, the industry has learned that a very effective way
of filtering sand from entry into the production tubing is to fill, or pack, the well
annulus with gravel, hence the term "gravel pack" completions.

A drawback to gravel pack completions arises when it is desired to connect a remotely-controllable flow control device to the production tubing to regulate the flow of production fluids from the gravel-packed well annulus into the production tubing, or to regulate the flow of injection fluids from the production tubing into the gravel-packed well annulus. If the flow control device is of the type that includes a flow port in the sidewall of the body establishing fluid communication between the well annulus and the interior of the tool (such as the flow control device disclosed in U. S. Patent No. 5,823,623), then the presence of gravel pack in the annulus adjacent the flow port may present an obstacle to the proper functioning of the flow control device, to the extent that the gravel pack may prohibit laminar flow through the flow port. As such, it is an object of the present invention to provide a flow control device that will enable the remote control of flow of production fluids and/or injection fluids in well completions where the annulus is packed with gravel. It is also an object of the present invention to provide such a tool that will enable the passage of wireline tools through the tool so that wireline intervention techniques may be performed at locations in the well below the flow control device.

SUMMARY OF THE INVENTION

An in-line flow control device for a well chokes flow through a conduit while allowing access therethrough.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures **1A-1I** taken together form a longitudinal sectional view of a specific embodiment of the flow control device of the present invention.

Figure **2** is a cross-sectional view taken along line **2-2** of Figure **1B**.

5 Figure **3** is a cross-sectional view taken along line **3-3** of Figure **1E**.

Figure **4** is a cross-sectional view taken along line **4-4** of Figure **1E**.

Figure **5** is a cross-sectional view taken along line **5-5** of Figure **1E**.

Figure **6** illustrates a planar projection of an outer cylindrical surface of a position holder shown in Figures **1C** and **1D**.

10 Figure **7** is a partial elevation view taken along line **7-7** of Figure **1I**.

Figure **8** is a longitudinal sectional view, similar to Figures **1A** and **1B**, showing an upper portion of another specific embodiment of the flow control device of the present invention.

15 Figure **9** is a longitudinal sectional view, similar to Figure **8**, showing an upper portion of another specific embodiment of the flow control device of the present invention.

Figure **10** is a schematic representation of a specific embodiment of a well completion in which the flow control device of the present invention may be used.

20 Figure **11** is a partial cross sectional view of an alternative embodiment of the present invention.

Figure 12 is a partial cross sectional view of an alternative embodiment of the present invention.

While the invention will be described in connection with the preferred embodiments, it will be understood that it is not intended to limit the invention to those embodiments. On the contrary, it is intended to cover all alternatives, modifications, and equivalents as may be included within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF THE INVENTION

For the purposes of this description, the terms “upper” and “lower,” “up hole” and “downhole” and “upwardly” and “downwardly” are relative terms to indicate position and direction of movement in easily recognized terms. Usually, these terms are relative to a line drawn from an upmost position at the earth’s surface to a point at the center of the earth, and would be appropriate for use in relatively straight, vertical wellbores. However, when the wellbore is highly deviated, such as from about 60 degrees from vertical, or horizontal, these terms do not make sense and therefore should not be taken as limitations. These terms are only used for ease of understanding as an indication of what the position or movement would be if taken within a vertical wellbore.

Referring to the drawings in detail, wherein like numerals denote identical elements throughout the several views, a specific embodiment of the downhole flow

Referring initially to Figure 1A, the device 10 may include a generally cylindrical body member 12 having a first bore (or first passageway) 14 extending from a first end 16 of the body member 12 and through a generally cylindrical extension member 17 (Figures 1E-1I) disposed within the body member 12, and a second bore (or second passageway) 18 extending from a second end 20 of the body member 12 and into an annular space 21 disposed about the extension member 17. In a specific embodiment, the diameter of the second bore 18 is greater than the diameter of the first bore 14. As shown in Figure 1E, the body member 12 may also include a first valve seat 22 disposed within the first bore 14, and the extension member 17 may include at least one flow port 24 establishing fluid communication between the annular space 21 and the first bore 14.

With reference to Figures **1B-1F**, the device **10** may further include a first generally cylindrical sleeve member **26** movably disposed and remotely shiftable within the first bore **14**. The manner in which the first sleeve member **26** is shifted within the first bore **14** will be described below. Referring to Figure **1E**, the first sleeve member **26** may include a second valve seat **28** adapted for cooperable sealing engagement with the first valve seat **22** to regulate fluid flow through the at least one flow port **24**. The first sleeve member **26** may also include at least one flow slot **30**.

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flow through the first bore **14**. The closure member **32** is shown in its closed position. In a specific embodiment, the closure member **32** may be a flapper having an arm **34** hingedly connected to the extension member **17**. The flapper **32** may be biased into its closed position by a hinge spring **36**. Other types of closure members

5 **32** are within the scope of the present invention, including, for example, a ball valve.

As shown in Figures **1F-1H**, the device **10** may further include a second sleeve member **38** movably disposed and remotely shiftable within the first bore **14** to move the closure member **32** between its open and closed positions. As shown in Figure **1E**, the second sleeve member **38** may include an inner surface **40** having a

10 locking profile **42** disposed therein for mating with a shifting tool (not shown). As shown in Figure **1G**, the second sleeve member **38** may also include at least one rib **44** that is shown engaged with a first annular recess **46** in the first bore **14** of the extension member **17**. In a specific embodiment, the second sleeve member **38** may include a plurality of ribs **44** disposed on a plurality of collet sections **48** in the

15 second sleeve member **38** that may be disposed between a plurality of slots **50** in the second sleeve member **38**. As will be more fully discussed below, the second sleeve member **38** may be shifted downwardly to engage the ribs **44** with a second annular recess **47** in the first bore **14** of the extension member **17**. The second sleeve member **38** may further include at least one first equalizing port **52** for cooperating

20 with at least one second equalizing port **54** in the extension member **17** to equalize pressure above and below the flapper **32** prior to shifting the second sleeve member

38 downwardly to open the flapper 32. The first equalizing port 52 establishes fluid communication between the inner surface 40 of the second sleeve member 38 and the first bore 14 of the extension member 17. The second equalizing port 54 establishes fluid communication between the first bore 14 of the extension member 17 and the annular space 21. A first annular seal 56 and a second annular seal 58 may be disposed within the first bore 14 of the extension member 17 and in sealing relationship about the second sleeve member 38. The second equalizing port 54 is disposed between the first and second annular seals 56 and 58. When the ribs 44 on the second sleeve member 38 are engaged with the first annular recess 46 in the extension member 17, the first annular seal 56 is disposed between the first and second equalizing ports 52 and 54, and a distal end 39 of the second sleeve member 38 is spaced from the closure member 32.

When it is desired to open the flapper 32, to enable passage of wireline tools (not shown) to positions below the device 10, a wireline shifting tool (not shown) may be engaged with the locking profile 42 (Figure 1G) and used to shift the second sleeve member 38 downwardly until the distal end 39 (Figure 1H) of the second sleeve member 38 comes into contact with the flapper 32. This will align the first and second equalizing ports 52 and 54, and thereby establish fluid communication between the annular space 21 and the inner surface 40 of the second sleeve member 38. In this manner, pressure may be equalized above and below the flapper 32 prior to opening of the flapper 32. The second sleeve member 38 may then continue

downwardly to push the flapper **32** open, without having to overcome upward forces imparted to the flapper **32** by pressure below the flapper **32**. It is noted, with reference to Figure **1E**, that pressure above and below the flapper **32** may also be equalized prior to opening of the flapper **32** by shifting the first sleeve member **26** to

5 separate the first and second valve seats **22** and **28** to establish fluid communication between the annular space **21** and an inner surface **27** of the first sleeve member **26**.

With reference to Figures **1I** and **7**, the device **10** may further include a cone member **60** connected to a distal end **62** of the extension member **17**. In a specific embodiment, the cone member **60** may include a first and a second half-cone

10 member **64** and **66**, each of which may be hingedly attached to the distal end **62** of the extension member **17**, as by a first and a second hinge pin **68** and **70**, respectively, and biased towards each other, as by first and second hinge springs **72** and **74**, respectively. The springs **72** and **74** bias and hold the half-cone members **64** and **66** in mating relationship, or in a normally-closed position, to form a cone, as

15 shown in Figure **1I**. In this normally-closed position, the cone member **60** directs fluid flowing from the second end **20** of the body member **12** into the annular space **21**, and functions to minimize turbulence as fluid flows into the annular space **21**. In this regard, in a preferred embodiment, an angle α formed between a first outer surface **65** of the first half-cone member **64** and a second outer surface **67** of the

20 second half-cone member **66** may be approximately forty-four (44) degrees when the half-cone members **64** and **66** are biased towards each other to form a cone, as

member 12, by application of pressurized fluid to the first side 80 of the piston 76. A

number of mechanisms for biasing the first sleeve member **26** upwardly, or towards the first end **16** of the body member **12**, may be provided within the scope of the present invention, including but not limited to another hydraulic conduit, pressurized gas, spring force, and annulus pressure, and/or any combination thereof.

5 In a specific embodiment, as shown in Figure **1A**, the biasing mechanism may include a source of pressurized gas, such as pressurized nitrogen, which may be contained within a sealed chamber, such as a gas conduit **82**. An upper portion **84** of the gas conduit **82** may be coiled within a housing **85** formed within the body member **12**, and a lower portion **86** of the gas conduit **82** (Figure **1B**) may extend
10 outside the body member **12** and terminate at a fitting **88** connected to the body member **12**. The gas conduit **82** is in fluid communication with a second side **90** of the piston **76**, such as through a second passageway **92** in the body member **12**. Appropriate seals are provided to contain the pressurized gas. As shown in Figure **3**, the body member **12** may include a charging port **94**, which may include a drill core
15 valve, through which pressurized gas may be introduced into the device **10**.

Another biasing mechanism is shown in Figure **8**, which is a view similar to Figures **1A** and **1B**, and illustrates an upper portion of another specific embodiment of the present invention, which is referred to generally by the numeral **10'**. The lower portion of this embodiment is the same as shown in Figures **1C-1I**. In this
20 embodiment, a second hydraulic conduit **96** is connected between a source of hydraulic fluid (not shown), such as at the earth's surface (not shown), and the body

member **12'**, and is in fluid communication with the second side **90'** of the piston **76'**, such as through the second passageway **92'** in the body member **12'**. As such, in this embodiment, hydraulic fluid is used instead of pressurized gas to bias the first sleeve member **26'** towards the first end **16'** of the body member **12'**.

5 Another biasing mechanism is shown in Figure **9**, which is a view similar to Figure **8**, and illustrates an upper portion of another specific embodiment of the present invention, which is referred to generally by the numeral **10''**. The lower portion of this embodiment is as shown in Figures **1C-1I**. In this embodiment, a spring **98** is disposed within the first bore **14''**, about the first sleeve member **26''**,
10 and between an annular shoulder **100** on the body member **12''** and the second side **90''** of the piston **76''**. As such, in this embodiment, force of the spring **98** is used instead of pressurized gas or hydraulic fluid to bias the first sleeve member **26''** toward the first end **16''** of the body member **12''**. Alternatively, as shown in Figure **9**, the device **10''** may also include a port **102** in the body member **12''** connected to
15 a conduit **104** through which hydraulic fluid or pressurized gas may also be applied to the second side **90''** of the piston **76''** to assist the spring **98** in biasing the first sleeve member **26''** toward the first end **16''** of the body member **12''**. In this regard, if hydraulic fluid is desired, the conduit **104** may be a hydraulic conduit, such as the second hydraulic conduit **96** shown in Figure **8**. Alternatively, if pressurized gas is
20 desired, the conduit **104** may be a gas conduit, such as the gas conduit **82** shown in Figures **1A-1B**. In another specific embodiment, instead of using hydraulic fluid or

pressurized gas, the port **102** may be in communication with annulus pressure, which may be used to bias the first sleeve member **26"** toward the first end **16"** of the body member **12"**, either by itself, or in combination with the spring **98**.

Referring now to Figures **1C-1D** and **6**, the device **10** of the present invention

5 may also include a position holder to enable an operator at the earth's surface (not shown) to remotely locate and maintain the first sleeve member **26** in a plurality of discrete positions, thereby providing the operator with the ability to remotely regulate fluid flow through the at least one flow port **24** in the extension member **17** (Figure **1E**), and/or through the at least one flow slot **30** in the first sleeve member

10 **26** (Figure **1E**). The position holder may be provided in a variety of configurations. In a specific embodiment, as shown in Figures **1C-1D** and **6**, the position holder may include an indexing cylinder **106** having a recessed profile **108** (Figure **6**), and be adapted so that a retaining member **110** (Figure **1D**) may be biased into cooperable engagement with the recessed profile **108**, as will be more fully explained below. In

15 a specific embodiment, one of the position holder **106** and the retaining member **110** may be connected to the first sleeve member **26**, and the other of the position holder **106** and the retaining member **110** may be connected to the body member **12**. In a specific embodiment, the recessed profile **108** may be formed in the first sleeve member **26**, or it may be formed in the indexing cylinder **106** disposed about the first

20 sleeve member **26**. In this embodiment, the indexing cylinder **106** and the first sleeve member **26** are fixed to each other so as to prevent longitudinal movement

relative to each other. As to relative rotatable movement between the two, however, the indexing cylinder **106** and the first sleeve member **26** may be fixed so as to prevent relative rotatable movement between the two, or the indexing cylinder **106** may be slidably disposed about the first sleeve member **26** so as to permit relative
5 rotatable movement. In the specific embodiment shown in Figure **1C-1D**, in which the recessed profile **108** is formed in the indexing cylinder **106**, the indexing cylinder **106** is disposed for rotatable movement relative to the first sleeve member **26**, as per roller bearings **112** and **114**, and ball bearings **116** and **118**.

In a specific embodiment, with reference to Figure **1C-1D**, the retaining
10 member **110** may include an elongate body **120** having a cam finger **122** at a distal end thereof and a hinge bore **124** at a proximal end thereof. A hinge pin **126** is disposed within the hinge bore **124** and connected to the body member **12**. In this manner, the retaining member **110** may be hingedly connected to the body member **12**. A biasing member **128**, such as a spring, may be provided to bias the retaining
15 member **110** into engagement with the recessed profile **108**. Other embodiments of the retaining member **110** are within the scope of the present invention. For example, the retaining member **110** may be a spring-loaded detent pin (not shown).

The recessed profile **108** will now be described with reference to Figure **6**, which illustrates a planar projection of the recessed profile **108** in the indexing
20 cylinder **106**. As shown in Figure **6**, the recessed profile **108** preferably includes a plurality of axial slots **130** of varying length disposed circumferentially around the

indexing cylinder **106**, in substantially parallel relationship, each of which are adapted to selectively receive the cam finger **122** on the retaining member **110**.

While the specific embodiment shown includes twelve axial slots **130**, this number should not be taken as a limitation. Rather, it should be understood that the present

5 invention encompasses a recessed profile **108** having any number of axial slots **130**. Each axial slot **130** includes a lower portion **132** and an upper portion **134**. The upper portion **134** is recessed, or deeper, relative to the lower portion **132**, and an inclined shoulder **136** separates the lower and upper portions **132** and **134**. An upwardly ramped slot **138** leads from the upper portion **134** of each axial slot **130** to
10 the elevated lower portion **132** of an immediately neighboring axial slot **130**, with the inclined shoulder **136** defining the lower wall of each upwardly ramped slot **138**.

In operation, the first sleeve member **26** is normally biased upwardly, so that the cam finger **122** of the retaining member **110** is positioned against the bottom of the lower portion **132** of one of the axial slots **130**. When it is desired to change the
15 position of the first sleeve member **26**, hydraulic pressure should be applied from the first hydraulic conduit **78** (Figure **1B**) to the first side **80** of the piston **76** for a period long enough to shift the cam finger **122** into engagement with the recessed upper portion **134** of the axial slot **130**. Hydraulic pressure should then be removed so that the first sleeve member **26** is biased upwardly, thereby causing the cam finger **122** to
20 engage the inclined shoulder **136** and move up the upwardly ramped slot **138** and into the lower portion **132** of the immediately neighboring axial slot **130** having a

different length. It is noted that, in the specific embodiment shown, the indexing cylinder **106** will rotate relative to the retaining member **110**, which is hingedly secured to the body member **12**. By applying and removing pressurized fluid from the first side **80** of the piston **76**, the cam finger **122** may be moved into the axial slot **130** having the desired length corresponding to the desired position of the first sleeve member **26**. This enables an operator at the earth's surface to shift the first sleeve member **26** into a plurality of discrete positions and control the distance between the first and second valve seats **22** and **28** (Figure **1E**), and thereby regulate fluid flow through the at least one flow port **24** and/or the at least one flow slot **30**.

Methods of using the flow control device **10** of the present invention will be now be explained in connection with a specific embodiment of a well completion denoted generally by the numeral **140**, as illustrated in Figure **10**. Referring now to Figure **10**, the well completion **140** may include a production tubing **142** extending from the earth's surface (not shown) and disposed within a well casing **144**, with a first packer **146** connected to the tubing **142** and disposed above a first hydrocarbon formation **148**, and a second packer **150** connected to the tubing **142** and disposed between the first hydrocarbon formation **148** and a second hydrocarbon formation **152**. A well annulus **154** may be packed with gravel **155**. A first sand screen **156** may be connected to the tubing **142** adjacent the first formation **148**, and a second sand screen **158** may be connected to the tubing **142** adjacent the second formation **152**. A first flow control device **10a** of the present invention may be connected to

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The flow control device **10** of the present invention may be used to produce hydrocarbons from a formation, such as formation **148** or **152**, to the earth's surface, or to inject chemicals from the earth's surface (not shown) into the well annulus **154**, and/or into a hydrocarbon formation, such as formation **148** or **152**. If the device **10** is to be used for producing fluids, then the device **10** should be positioned with the first end **16** of the device **10** (Figure **1A**) above the second end **20** of the device **10** (Figure **1I**). But if the device **10** is to be used to inject chemicals, then the device **10** should be positioned "upside down" so that the second end **20** is above the first end **16**.

Figure **11** discloses an alternative embodiment of the present invention. As shown in the figure, the device **10** has a body **12** defining a first bore **14** therethrough. A second bore **18** in the annular space **21** of the body **12** provides an alternate pathway through the body **12**. As in the previously described embodiment, flow through the second bore **18**, which may be annular or one or more discrete passageways in the annular space **21**, is controlled by a sleeve valve. The sleeve valve comprises a sleeve member **26** having a plurality of sleeve ports **200** therein (the sleeve ports may be replaced by the flow slots **30** of the previous embodiments or other similar openings). However, in the embodiment shown in Figure **11**, the sleeve ports **200** comprise a plurality of discrete holes through the sleeve member **26**.

The sleeve ports **200** have a size selected to produce a specific flow area when opened to the flow port(s) **24** between the first bore **14** and the second bore(s) **18**.

For example, Figure 11 shows the sleeve member 26 in the fully open position in which all of the sleeve ports are positioned above the valve seat 22 in fluid communication with the flow port 24. In this position, the flow may be, in one example, full bore flow in which the flow area through the sleeve ports 200 is

5 approximately at least as great as the flow area of the first bore 14 or the second bore 18. The sleeve ports 200 are spaced longitudinally so that sleeve member may be positioned with the valve seat 22 between sets of sleeve ports 200 to define different preselected flow areas through the sleeve member. The position holder or indexing mechanism shown generally at 202 defines the discrete positions of the sleeve

10 member 26. The indexing mechanism may be the indexing sleeve described previously, another j-slot type indexer, or some other type of known indexer. Applying and removing pressure to the sleeve member 26 via the control line (or hydraulic conduit) 78 provides for selective positioning of the sleeve member 26. As mentioned previously, the sleeve member 26 generally has a biasing member such as

15 a pressurized balance gas in a gas conduit 82 to bias the sleeve member 26 in a give direction to facilitate operation.

The embodiment describe of the present invention described in connection with Figure 1 for example generally describes the present invention as including a flapper valve in the first bore 14, although the description clearly states that other

20 closure members 32 may be used (such as ball valves). The embodiment shown in Figure 11 discloses a removable plug 204 as the closure member 32. In general, the

plug includes a locating and positioning locator **206** (such as a profile and lock) to accurately position the plug in the well, and specifically the body **12**. The plug includes a seal **208** that abuts the first bore **14** which may include a polished bore receptacle to essentially block flow through the first bore **14**. Note however that

5 when the present description refers to closing a valve or blocking flow, some leakage or planned flow through the valve may be acceptable. Thus, in the present description, "closed" or "blocked" allows for some flow such as five or ten percent flow. The plug **204** is position between the inlet to the second bore **18** and the flow ports **18** so that, when the plug is in place, the fluid is routed through the second bore

10 **18** and the flow ports **24**. In this way, the fluid through the device **10** is regulated by the sleeve member **26** which may be, for example, controlled from the surface or a downhole controller. The plug **204** may be retrieved from the device **10** by a retrieving tool (not shown) which may be run into the well on a standard carrier line (e.g., wireline, slickline, coiled tubing). To facilitate positioning and retrieval, the

15 plug may use locking dogs, one or more collets, or other known positioning devices.

Figure **12** shows the sleeve member **26** in the closed position with the flow ports **24** below the valve seat **22**. The selective plug **204** is positioned in the device **10** in the nipple **212** having a selective profile as shown as the locator **206**.

Note that the first bore **14** generally provides access through the device (or

20 valve) **10** when the closure member **32** is open or removed and may therefore be referred to as the access bore or passageway. Thereby, tools may be passed through

the device **10** to, for example, re-enter the well. As an example, a wireline, slickline, or coiled tubing deployed tool could be run through the device **10** when the first bore **13** is open. Likewise, the second bore provides for fluid flow when the first bore **14** is closed and may therefore be referred to as a bypass or bypass flowpath or passageway.

Although described generally as a hydraulically controlled valve, the device could also be controlled electrically by replacing the hydraulic components with motors or solenoids or the like and electrical communication lines.

It is to be understood that the invention is not limited to the exact details of construction, operation, exact materials or embodiments shown and described, as obvious modifications and equivalents will be apparent to one skilled in the art. For example, while the device **10** has been described as being remotely controlled via at least one hydraulic conduit (e.g., conduit **78** in Figure **1A**), the device **10** could just as easily be remotely controlled via an electrical conductor and still be within the scope of the present invention. Additionally, while the device **10** of the present invention has been described for use in well completions which include gravel pack in the well annulus, the device **10** may also be used in well completions lacking gravel pack and still be within the scope of the present invention. Accordingly, the invention is therefore to be limited only by the scope of the appended claims.

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